Can't We All Just Get Along? Weaponry Standardization and Sharing at the Agate Basin Site

BY

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Abstract

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This study explores weaponry design as it relates to the organization of technology at the Agate Basin site. Specifically, I examine potential sharing of weaponry elements during communal hunts, and the implications of such sharing as they pertain to overall technological organization of Agate Basin hunting groups. By looking at sharing, this study represents a departure from typological lithic analyses and explores a behavioral aspect of Paleoindian technological organization. *K*-means cluster analysis is utilized to determine whether hafted-area morphologies on Agate Basin points are standardized and consistent with expectations we might have if sharing of weaponry elements was planned for in preparation for a communal hunt. It is argued that standardization and sharing of weapons was a reliable organizational technique potentially employed by Paleoindian hunters during seasonal aggregations that served to secure critical resources during a time when failure during a hunt would prove catastrophic.

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Introduction

This study is an exploration of weaponry design at the Agate Basin site as it relates to the organization of technology in the context of Paleoindian communal hunts. More specifically, it investigates the potential for sharing of weaponry elements between hunters during bison hunts. In order to accomplish this goal, haft-area morphology of Agate Basin projectile points are analyzed to determine if they were standardized to a degree where interchangeability of weaponry elements was possible. In doing so, this lithic analysis departs from many others in that the goal is not to understand typological or functional issues relating to technological systems, but to examine projectile point morphology as a way of exploring social and organizational aspects of Paleoindian behaviors.

The Agate Basin site was first excavated in 1942 by Frank Roberts, H.B. Roberts, and R.E. Frison, then in 1961 by William M. Bass and Frank Roberts, and finally by George Frison and the University of Wyoming from 1975 through 1980 (Frison and Stanford 1982:11-14). The site is located near the border between Wyoming and South Dakota on the Northwestern High Plains, adjacent to the southern portion of the Black Hills. Although it is a multi-component site, this study focuses specifically on the Agate Basin component. The Agate Basin techno-complex brackets between 10,500 14C years BP and 10,000 14C years BP (see Holliday 2000 and Sellet 2001 for an overview of Agate Basin chronology; and Larson et al. 2009 and Wormington 1984 for more background on the Agate Basin techno-complex). Lee et al. (2011) provide evidence from the Frazier site, a single component Agate Basin site, suggesting an age of 10,200- 10,100 14C years BP (CURL-11668 and

CURL-11671, respectively). Frison and Stanford report ages of 10,430±570 14C years BP (RL-557) on charcoal associated with the Agate Basin Area 2 bone-bed (Frison and Stanford 1982:179). This age coincides with the chronology developed by Irwin-Williams et al. (1973), situating the Agate Basin site within a generally accepted temporal framework for the Agate Basin techno-complex within the Early or Middle Paleoindian period.

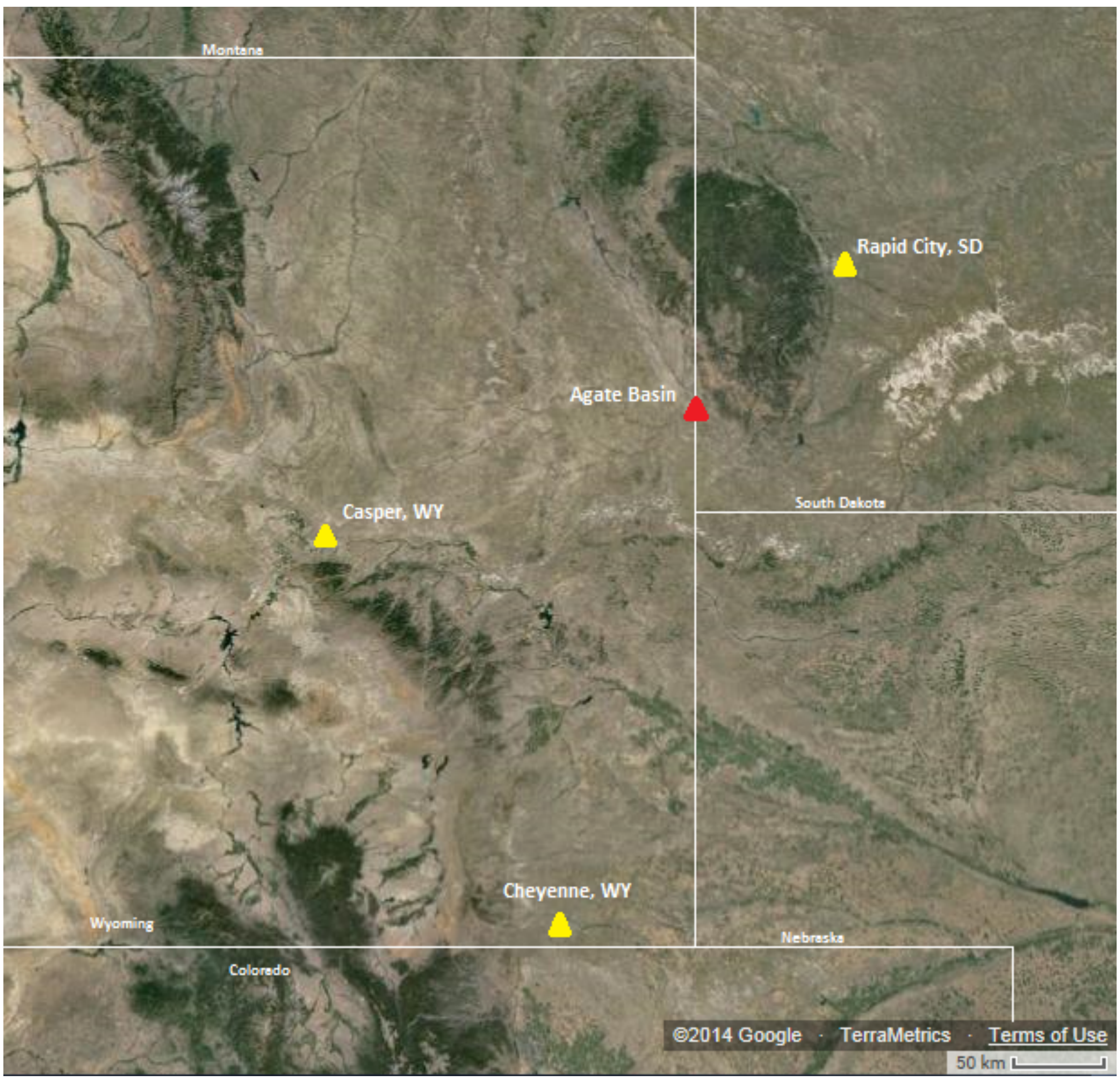

Figure 1. Map of Agate Basin Site Location. Photo from Google Maps 2014

Agate Basin projectile points are lanceolate in shape with flaking usually occurring at a right angle to the longitudinal axis of the point. Transverse cross-sections demonstrate a smooth, lenticular form, with a fine retouch applied to the blade edges. Marginal grinding occurs approximately from the point of greatest width near the center of the projectile, along the edges to the basal corners, although the bases themselves generally were not ground (Frison and Stanford 1982: 80-81). According to Bradley, these points may have employed a socketed haft rather than a split haft based on the tapering stem (Bradley 1974:194). Experiments with both socketed and nocked hafting mechanisms indicated socketed hafts functioned more effectively for Agate Basin points (Kornfeld et al. 2010:237). This study will explore the possibility of standardization, specifically focusing on the haft-area morphologies, as a potential indicator of the ability for hunters to exchange weaponry elements prior to or during the hunt at the Agate Basin site.

Aggregation, Gearing Up, Standardization, and Sharing

This study argues that potential for sharing of specific elements of a weaponry system is the result of organization of technology emphasizing quick interchangeability and replacement of weaponry elements through group-wide standardization of weaponry components. Additionally, for effectiveness in the context of an aggregated group activity such as communal bison hunting, this type of organization would need to take place at the level of the aggregated group.

Aggregation of Paleoindian hunter-gatherers has been hypothesized at numerous large bone-bed sites such as Agate Basin (Frison and Stanford 1982:79), and expansive campsites with numerous activity areas such as those at Whipple (Curran 1984), Nobles Pond (Seeman 1994), Bull Brook (Robinson et al 2009), and Lindenmeier (Wilmsen 1974). However, our understanding of aggregation in a Paleoindian context is still limited, thus we do not necessarily know what archaeological signatures we might expect at such a site, or even if the hypothesized sites mentioned above actually represent aggregations (Hofman 1994:342). Additionally, we should not expect aggregations to have taken the same form or have been done for the same reasons. Therefore, we must evaluate each site's case for representing aggregation in it's own specific context based on evidence from the material record and environmental factors.

Aggregations, although often associated with communal hunting activities during Paleoindian times, may have occurred when specific needs could not be met at the dispersed-group level. Aside from communal hunting, activities hypothesized to be associated with aggregations include group rituals, mate-finding opportunities, information and resource sharing, and obtaining short-term abundance of resources during times of stress (Curran 1984; Hayden 1982; Hofman 1994:345; Seeman 1994:281). Aggregation localities may have been selected not necessarily because of the presence of mobile resources such as bison, but rather because of other resources in the area (Hayden 1982; Hofman 1994), such as predictable shelter during the cold season, presence of fixed resources (i.e. water, wood, or predictable floral and/or faunal resources), or other social draws to a specific location (ritual or ceremonial draws, for example). Therefore, complexity of the surrounding environment likely played a major role in determining the location of a potential aggregation site. In the context of this paper, the primary aggregation activity being investigated is the communal hunt, but it is important to keep in mind that this was likely not the only reason, or even primary reason, bands potentially aggregated for the hunt at Agate Basin.

Hunting communally may have been less efficient than hunting in smaller groups in terms of energy expenditure (Hofman 1994). However, it emphasized reliability when failure would have been catastrophic (Hofman 1994). This was especially true during cold seasons when diversity of available resources decreased. Therefore, aggregation can be seen as an adaptive strategy used to secure ample amounts of food during times of resource stress (Curran 1984). Similarly, Frison (1993) suggested that communal hunts on the Plains often took place during late-fall through early-spring, and served the purpose of accumulating enough meat to last through even the roughest winter.

When considering the candidacy of Agate Basin as a communal hunting site, we must look at the number of animals and projectile points recovered from the site, number of hunting events represented, the extent of butchering evident in the faunal remains, and the nature of the environment of the High Plains in terms of resource availability. Hill recently calculated the MNI based on right metacarpals to be 41, although the MNI based on right astragali is 53 (Hill 2001:126). Additionally, he suggested the Agate Basin bone-bed represents a single hunting event based on a refinement of dentition analysis, a critical observation when determining aggregation (Hill 2001: 109). Since Zeimens (1982) estimated that only 20% of the original bone-bed was recorded, the likely number of actual animals killed was significantly larger. If we project the actual number of animals killed based on the most conservative MNI value obtained (MNI=41), we can hypothesize that 205 animals were killed -- a number too large for dispersed band hunters to kill in a single hunting event. The total amount of meat and/or hide obtained from a kill of this magnitude would have been significant, far too much for a single band, or even multiple bands, to consume or use over the course of a winter (see Wheat et al. 1972 for a discussion of the amount of meat procured from bison butchering). If the site represents a single kill, the a strong argument for aggregation can be made. Conversely, if the bone-bed at Agate Basin represents multiple temporally closely spaced kills, or separate kills that all occurred during the cold season, then the case of communal hunting becomes less obvious. Distinguishing between these possibilities requires high temporal resolution. Unfortunately, current methods do not permit conclusive resolution of the depositional history of the bone-bed at that scale. In the absence of better arguments, the assumption of a single kill, as hypothesized by Hill (2001), will be used here.

Hill (2001:139) inferred butchering practices focused on obtaining "high-utility upper limb food packages" based on an analysis of element frequency. This suggests intense butchering, at least in the absence of other retrievable evidence due to poor preservation (Zeimens 1982:226). The low proportion of complete projectile points recorded during the 1975-1979 excavations (13 complete points/46 total points= 28.3% complete points) suggests high recovery rates of usable projectile points after the hunt. This, in turn, implies relatively unrestricted access to a large amount of the bone-bed, also allowing for potentially large amounts of butchering (Hill 2001; Hofman 1999). However, the total number of recovered weapons throughout the entire history of excavation and collection from Areas 1 and 2 (n=169) suggests many hunters were involved. This is demonstrated by the fact that the points recovered during excavation represent only abandoned or lost artifacts (Frison and Stanford 1982). The projected total number of animals represented (MNI=205) and the number of points recovered (n=169) fits well with Hofman's assertion that number of animals will be greater than number of projectile points in a given Paleoindian bison bone-bed, an argument in favor of the large reconstructed number of animals noted above (Hofman 1999:136).

Significant raw material variability exists within the assemblage that, based on an examination of maintenance patterns explored below, suggests that groups exploited different areas prior to the hunt and converged at the Agate Basin site for a big-game hunt. Hofman (1994) noted that the High Plains was an ecologically complex area during Paleoindian times, which would have provided a number of predictable resources available for foraging, even during winter months. Dentition analysis indicates that killing and processing took place during a cold season, fitting well with the idea hunters will procure food in larger amounts for the purpose of overwintering (Frison 1993; Frison and Stanford 1982:79).

Table 1. Raw Material Sources and Distances to the Agate Basin Site. Data from Hill (2001).

Raw Material	Distance from Agate Basin (in kilometers)
Knife River Flint	~ 500 km
Mississippian Chert	< 100 km
Pennsylvanian Chert	< 100 km
Lower Cretaceous Quartzite	< 100 km
Upper Jurassic Morrison formation quartzite	< 100 km

Although he argued for a single kill, Hill (2001:253) suggested the site represents a small hunting group that took advantage of fortuitous circumstances, having used a hunting strategy (an arroyo trap) that did not necessarily take a large number of hunters to execute (see also Hofman 1994:359). While certainly possible, this explanation does not adequately accomodate the large number of points recovered from the bone-bed. Instead, I suggest a more parsimonious explanation of a hunt with a large number of participants. The projected number of weapons used, the lithic raw material variability within the weaponry assemblage, the number of animals killed, the amount of meat which would have been procured, and the large amount of butchering suggest a massive undertaking requiring many individuals to cooperate.

Gearing up is critical in the context of the Agate Basin site: such a large communal hunting activity would have likely necessitated prior planning to ensure enough weapons were present in hunters' toolkits. Gearing up has been defined by Sellet (2004:1561) as "a situation in which hunters manufacture tools in excess of their needs, in anticipation of future events". Such preparation was likely employed at communal hunting sites, as it ensured enough weapons had been manufactured in anticipation of a large hunting event or multiple closely spaced events. Gearing up in this situation was a method of risk reduction, as it likely produced more weapons than were needed. Failure of a communal hunt could have been catastrophic and affected a large number of people. Gearing up, then, is a critical concept when exploring the Agate Basin site as a large-scale communal bison kill.

Technologically, Agate Basin weaponry systems consisted of points, hafting mechanisms, possible foreshafts, main shafts, and delivery systems. The projectile point is the most visible element of most Paleoindian weaponry systems, as most points are made of non-perishable stone. Bone weapons are argued to have been used during Paleoindian times as well, although they are much less common in the archaeological record (Frison and Zeimens 1980; Waters et al 2011). Thus, stone projectile are the artifacts we can use to formulate our hypotheses and arguments about standardization and sharing practices. The haft secured the projectile point to the shaft or foreshaft of a specific weapon. Marginal grinding on Agate Basin projectile points has been inferred to represent the portion of the point within the haft (Frison and Stanford 1982). The tapering base suggests these points were hafted using some form of socketing technique (Bradley 1974:194), where the base and a large amount of the point itself were placed in and were completely surrounded by the haft. Foreshafts were inserted into the main shaft, containing a hafted point on one end while the other end was placed and fastened into the main shaft. Evidence comes from the Anzick Clovis site, where beveled bone "rods" may have served as foreshafts for Clovis weapons (Stanford 1996). Additionally, Stanford

(1996) described an antler foreshaft socket found at a site in Indiana dating from between 10,000- 7,000 14C years BP.

Standardization of foreshafts implies a weaponry system which emphasizes interchangeability and quick replacement during hunts, qualities which might indicate that sharing of component parts of the weaponry system was part of the hunt preparation and organization. A key component of any given weaponry system is the manner in which the weapons are delivered. Aerial weapons include darts and atlatls and allow for delivery from a distance. Bows and arrows also fall into this category, but were not introduced on the Plains until the Late Prehistoric period (Kornfeld et al. 2010**;** Nassaney and Pyle 1999). Thrusting spears require hunters to be in close proximity to the prey. Traps such as corrals, where animals can be reasonably contained and temporarily immobilized while hunters can stand on the outside of the trap and thrust, suit the abilities and advantages of a spearing mechanism. Additional strategies specifically effective for bison hunting with atlatls and/or spears include arroyo head-cuts, parabolic sand dunes, steep talus slopes, and drive lanes (Frison 1991:23; Frison 1993:245; Frison 2004). Site topography and layout of the bone-bed at Agate Basin indicate hunters likely used some form of arroyo head-cut trap, artificial barrier, corral, or some combination of the three in trapping and killing their prey (Frison and Stanford 1982:269; Kornfeld et al 2010:223).

Two critical concepts for this study are standardization of weaponry system elements, and the implications of standardization on sharing of weaponry elements in the context of the organization of technology in preparing for communal bison hunts. It is being hypothesized that standardization within a weaponry system may be indicative of sharing of weaponry elements in preparation for or during a hunt. Standardization refers to the relative measure of the degree to which artifacts are made to be the same (Eerkens and Bettinger 2001:493). As the main interest is in standardization of haft-area morphology, this study focuses on characteristics of haft-area morphology on Agate Basin projectile points to determine if weapons from the same system form one or several homogenous group(s) of weapons, based on haft-area attributes. Sharing, trading, and/or exchange of standardized foreshafts may have occurred among Agate Basin hunter-gatherers prior to or at the hunt, if weapons were standardized enough to enable exchange of points and other elements. This would produce a minimal number of homogenous clusters within an assemblage. Group-wide standardization is key to a group's potential for sharing, as foreshafts need to be similar enough morphologically that hunters can replace broken or lost parts without loss in functionality or convenience. If parts of weapons are not standardized, their reliability within a system is severely limited in terms of sharing between hunters and they will only be functional in their initial form. If the point breaks or is irretrievable until after the hunt, that weapon or foreshaft system is useless until after the next refurbishing event or until the weapon is retrieved during butchering. Furthermore, in this scenario, sharing of weapons is possible only if one hunter lends an entire spear or dart to another hunter, as each hunter would only have his/her own replacement parts.

These issues highlight the importance of foreshafts if flexibility, reliability, and sharing prior to or during a hunt are organizational goals. Group-wide standardized foreshafts not only allow hunters to replace lost or damaged points quickly during the hunt from within their own toolkit, they also allow them to carry several foreshafts at once for quick sharing. Additionally, foreshafts maximize preservation and recovery of main shafts during the hunt, as they can be left lodged in the animal if the point gets stuck. In short, standardized foreshafts provide a number of beneficial attributes, including the potential ability to share weaponry elements during the hunt and quick replacement of broken or lost foreshafts, making hunting more efficient, flexible, and reliable. Higher levels of standardization give hunter-gatherer groups more opportunities to share parts of a weaponry system.

When technology is organized to emphasize group-wide standardization, sharing of parts within the system is increasingly possible. If we see evidence of group-wide standardization of component parts of weaponry at communal hunts, it implies that some mechanism for organization of technology at an aggregated level was employed among people who do not live together year round. This suggests high levels of organization were significant attributes at the basic family unit, multiple family units, and even aggregated bands. This concept takes the study from being specifically about standardization of weapons to one with potential to inform hypotheses about organization at a much greater scale.

If we determine sharing of weaponry elements within a weaponry system is plausible, the next question becomes: why share in the first place? One explanation for sharing of resources in hunter-gatherer societies is altruistic risk reduction. Hill (2002) argued that high degrees of cooperation during the hunt among the Ache in

South America is a way to increase food consumption among all people within a residential group. Such a method of cooperation and sharing of resources (including food resources, tools, labor in construction, and other tasks) can be seen as a method for reducing risk of resource depletion in times of resource stress (Hill 2002:123). However, in the case of the Ache, cooperation does not happen solely in times of resource stress, but is present in nearly every element of their lives (Hill 2002). Cooperation and sharing appear to have been built into their social structure. Sharing is not necessarily a practice always done for egalitarian or risk reduction reasons, however. Hawkes et al. (2001), for example, suggested meat sharing among Hadza hunters is done not for the purpose of familial provisioning, but it is an important way for males to affect their social standing (Hawkes et al. 2001:134). They also discussed tolerated theft, the practice of allowing others to "steal" excess resources from another individual because it would cost the "victim" more to defend the resource than it is worth to the owner (Hawkes 1992:284). Alternatives to risk reduction may better explain the practice of sharing of unpredictably acquired goods, a category which includes big game meat (Hawkes 1992:300). Peterson (1993) asserted "demand sharing", defined as sharing in response to "direct verbal and/or non-verbal demands" (Peterson 1993:860), is a common practice in aboriginal Australia. Bird et al. (2002) likewise demonstrated a negative relationship between increased risk and increases in sharing practices, suggesting instead that food sharing among the Meriam in Australia is related to acquiring social status instead of an altruistic method for reducing group-wide risk.

These examples cannot simply be projected directly upon Agate Basin hunter-gatherers, as they come from vastly different time periods and geographic locations. Additionally, these arguments are made primarily for sharing resources that are the ultimate result of communal resource-gathering activities, not sharing during the actual resource acquisition process (aside from Hill's (2002) description of the Ache). Projectile points represent extractive technology in that they functioned in the procurement of resources. Sharing of extractive technologies has different implications than sharing the resources obtained through use of extractive technology givin that sharing of weaponry during a hunt can often be seen as a method of risk buffering, although Hayden (1982) argued sharing of projectile points during Paleoindian times was a way of cultivating and maintaining critical inter-band alliances and relationships. Weapon sharing is also ethnographically demonstrated to be related to meat sharing, with the maker of arrows, not necessarily the hunters themselves, receiving a significant share of the meat, creating incentive for hunters to share their weapons (Weltfish 1965: 138; Wiessner 1983). Sharing of weapons while on the hunt, however, ensures hunters are properly provisioned with reliable weaponry that allow elements to be quickly exchanged or shared should individuals run out of functional weapons. It allows for the entire hunting group to be active and effective for longer. The Agate Basin assemblage was selected for this study because a significant extractive toolkit was recovered in direct association with hunting activity, allowing for exploration of sharing of explicitly extractive tools, which has different implications for cooperative behavior and sharing practices.

Standardization can take many forms in the archaeological record. One might observe a system in which artifacts do not appear standardized based on the measurements used in the analysis, but instead fall into a continuum of forms and morphological elements. This situation likely makes exchange and sharing of elements of the system difficult. We might see artifacts cluster into a small number of standardized groups within which there is internal consistency of morphological features. Standardization of weapons in such a way enables for exchange and replacement of parts, so long as the weapons being exchanged and replaced fall within the same homogenous cluster. In order to ensure manufacture and maintenance of functional weaponry components, technology must be organized to emphasize standardization and internal consistency at a group-wide scale, implying some social mechanism enforcing such a system. Such standardization may result from three distinct processes. It may indicate two or three functionally distinct weapons within a weaponry system (i.e. darts and thrusting spears). It could also represent standardization of weapons at a group level, where each hunter is responsible for manufacturing his or her own hunting toolkit within enforced specifications throughout the entire group. Finally, a third scenario involves the use of specialists to manufacture and maintain all hunting implements (Gelo 1986**;** Root 1997; Weltfish 1965). Intentional standardization, however, is not the only process through which we might find such a pattern of variability in the archaeological record. Specialists, or individuals who produce more tool than can be used by his/her own household (Root 1997), might be responsible for a standardized weaponry system not out of any organization scheme emphasizing the ability to exchange and share parts, but due to the fact that one person might manufacture all tools in the same way, resulting in a partially homogenous collection of tools due to the repeatability of manufacturing processes by an individual tool-maker (Weltfish 1965).

We might also observe an assemblage containing significant variability, but rather than being along a continuum, artifacts cluster into a large number of homogenous groups based on morphological attributes. This is a system in which individuals are responsible for their own weapons, which are standardized within the individual toolkit. However, variability between individual hunters' toolkits would inhibit sharing of weaponry between individuals. Ethnographic studies documented Awá hunters manufacturing their own weaponry individually and produce highly individualized weapons functional specifically with their own individualized bow (González-Ruibal et al 2011). The result, again, is highly standardized arrows. However, while within each hunter's toolkit there would be internal consistency of morphological attributes of each weapon, such consistency would be lacking *between* toolkits. Such a system would essentially eliminate the ability for hunters to share or exchange their weapons with others, as each weapon is individualized to a high extent.

Finally, one might observe a situation where all artifacts fall within one morphologically similar group based on specific attributes. Complete internal consistency would be demonstrated throughout the system and result in each element being completely interchangeable. The only scenarios where this situation might exist, however, are situations where either a single manufacturer produced weapons for the entire system while working from an extremely specific template, or where multiple producers work from the same specific template. These ideas will be tested with data from the Agate Basin site to determine what form, if any, standardization takes at the site.

Methods

Measurements of ground width, defined as the width where basal grinding stops, and ground length, defined as the maximal length from the horizontal plane indicating the end of grinding to the proximal tip of the point, will be explored in the context of standardization. Ground width is critical for point security within the haft, as excess space between haft boundaries and lateral margins of points introduces horizontal instability of the point within the haft, potentially making the weapon less predictable and effective. Minor differences between this width and the width of the haft opening could be overcome by placing grass, leather, or some other form of filler into the gap. For the weapon to be maximally efficient, however, these two values should be relatively similar. If not, excess space between haft and point will hinder penetration. Thus, ground width is indicative of the width of the opening of the hafting mechanism of the shaft or foreshaft into which the point was inserted. Variability in ground length, although potentially not as critical to point security could be handled much in the same fashion as ground width (e.g. using grass, leather, or some other type of filler).

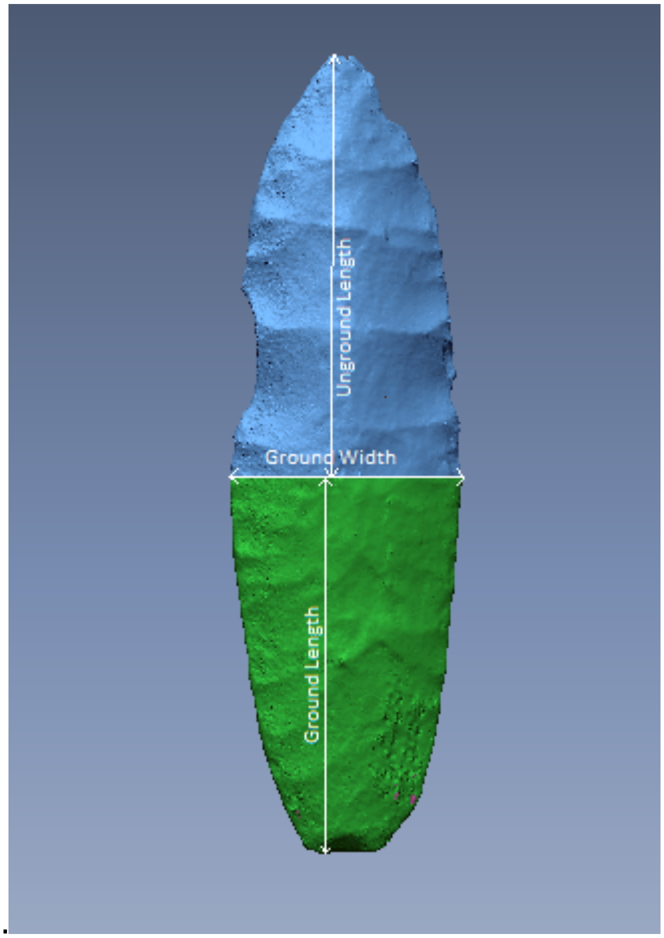

Figure 2. Indication of Measurement Locations. 3D Scan of Catalog Number 35010a.

Ground length gives us a minimum value for the depth of the haft, as the ground length must be able to fit into the haft up to the point where marginal grinding terminates if grinding is a proxy for hafted area. A regression analysis of the 19 complete Agate Basin projectile points suitable for analysis in this study indicates a moderate relationship between ground width and ground length (r^2=0.49; y=0.7002+1E-09). Combined, these two measurements give us a good idea about the size of socketed haft openings in this assemblage.

A sample of 39 points and fragments from the Agate Basin site collection, housed at the University of Wyoming, was examined for this study. However, only points determined to be retain complete hafted areas could be used for this analysis. Additionally, complete points also enabled calculation of a resharpening index, as explained below. These restrictions lower the sample size to 19.

Cluster analysis has been used often in recent archaeological research to determine if internal structures exist within specific data sets (Hirshman et al 2009**;** Read and Russell 1996**;** Sutton and Reinhard 1995). The data here were clustered using IBM SPSS Statistics software (Version 21). *K*-means cluster analysis was used to determine standardization, using Mojena's "Stopping rule one" to determine the optimal number of clusters within the data (Aldenderfer and Blashfield 1984; Milligan and Cooper 1985; Mojena 1977; Mooi and Sarstedt 2011). One issue with utilizing cluster analysis in archaeological inquiry is the lack of a mathematical level of significance associated with the results, necessitating other methods for verification. One technique involves splitting the data into two groups and running *K*-means cluster analysis on each of these groups independently, testing for internal consistency in the initial cluster solution (Mooi and Sarstedt 2011;Aldenderfer and Blashfield 1984:65). If the same clusters are observed in both split and complete data sets, the confidence in the initial clustering solution is strengthened (Aldenderfer and Blashfield 1984:65). If objects change cluster membership at a high rate, the initial cluster partition is weak. A second method for validation is use of alternative clustering procedures to determine if the data cluster together when different clustering algorithms are used (Mooi and Sarstedt 2011:260). Some variation between solutions using this technique is expected, as the methods used in the different hierarchical algorithms can be significantly different. However, if the data clusters in roughly the same way despite using different clustering algorithms, the initial clustering solution is supported (Mooi and Sarstedt 2011:260). Data was standardized through calculation of Z-scores for each variable in order to correct for large differences in standard deviation between the two variables (Tanioka and Yadohisa 2012).

Results

Ground length and ground width values for 19 artifacts were plotted on a Cartesian grid in order to observe any superficial patterning. Visual inspection indicates the potential for 3 or 4 potential clusters. Employing a Within-groups linkage hierarchical clustering method with Squared Euclidean distance as an interval method, "Stopping rule one" indicates a three-cluster solution is optimal for this data set. As such, a 3-cluster K-means clustering solution was used as the optimal partition of the data set. Cluster membership for each point observed can be viewed visually in Figure 3 below (page 21, this document).

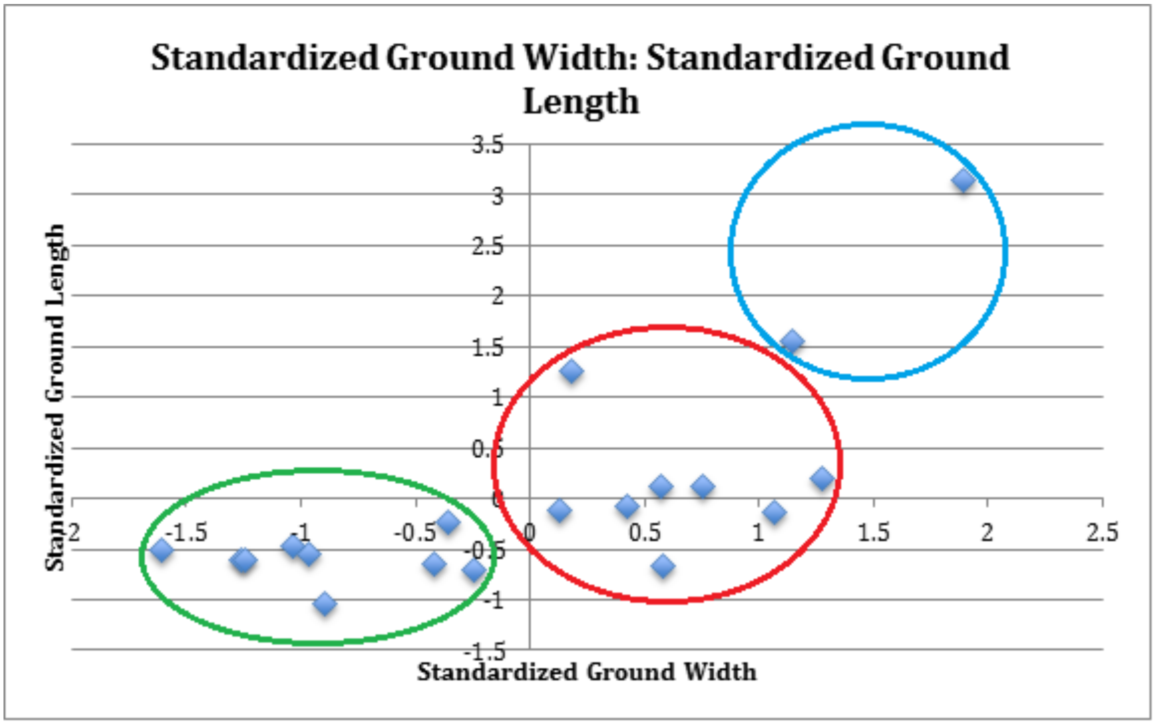

Figure 3. Indication of Cluster Membership for Complete Agate Basin Projectile Points Used. X-axis represents standardized ground width values. Y-axis represents standardized ground length values. Artifacts within same circle have common cluster membership

Table 2. Mean Cluster Data for Ground Width and Ground Length

Cluster ID	Mean Ground Width	Mean Ground Length	Number of Artifcts
Cluster 1	17.7 mm	32.4 mm	9
Cluster 2	23.4 mm	42.9 mm	8
Cluster 3	26.7 mm	77.9 mm	2

Table 3. Analyzed Assemblage Data

Cat #	TLen (mm)	GLen (mm)	GWid (mm)	Ground Volume (mm^3)	StGLen	StGWid	Margins	Base	RMat	Mem	RI
35004a	53.7	31.65	19.46	2149.28	-0.65	-0.42	Curved	Round	Chert	1	0.63
11317	142.6	60.9	21.7	4456.62 (geometric)	1.25	0.18	Curved	Straight	KRF	2	1.08
35010a	83.96	39.45	25.01	3192.36	-0.14	1.07	Curved	Concave	Quartz	2	0.97
35011a	60.48	32.32	16.32	1617.78	-0.60	-1.26	Curved	Crushed	Chert	1	0.78
35009a	62.35	31.22	23.19	2430.81	-0.67	0.58	Curved	Straight	Quartz	2	0.91
0A287	55.30	25.55	17.67	1083.34	-1.04	-0.90	Curved	Straight	Chert	1	1.13
0A379	65.2	32.3	16.4	1337.36 (geometric)	-0.60	-1.24	Curved	Round	KRF	1	0.92
96221	87.27	38.0	19.69	2250.08	-0.23	-0.36	Straight	Concave	Chert	1	1.13
96085	80.07	43.44	23.16	3897.66	0.12	0.57	Curved	Straight	Chert	2	0.71
96060	83.83	40.35	22.62	3170.09	-0.08	0.43	Curved	Crushed	Chert	2	0.93
11319	68.27	43.36	23.85	3398.09	0.11	0.76	Curved	Concave	KRF	2	0.49
96601/ 96237	112.5	65.63	25.29	5853.45 (geometric)	1.56	1.14	Straight	Straight	KRF	3	0.57
98605	88.48	44.79	25.77	4325.63	0.21	1.27	Curved	Round	KRF	2	0.82
11307	73.25	32.98	17.43	1542.54	-0.56	-0.96	Curved	Straight	KRF	1	1.09
0A051	69.05	33.74	15.03	1235.30	-0.51	-1.61	Curved	Round	KRF	1	0.93
96107a	83.06	39.70	21.52	3047.07	-0.12	0.13	Curved	Straight	KRF	2	0.94
0A176/ 96094/ 96094a/ 0A458	188.7	90.1	28.1	8771.45 (geometric)	3.14	1.90	Curved	Round	KRF	3	0.85
96228	57.41	30.67	20.13	2113.16	-0.71	-0.24	Curved	Straight	KRF	1	0.80
96076	48.89	34.29	17.17	1633.12	-0.47	-1.03	Straight	Straight	Quartz	1	0.38

Chart Key: Cat#= Catalog Number; TLen=Total Length; Glen= Ground Length; Ground Volume (3D obtained unless otherwise stated; geometric indicates formula for triangular prism used); StGLen= Standardized Ground Length; StGWid= Standardized Ground Width; RMat= Raw Material (Chert= various cherts, KRF= Knife River Flint, Quartz= various quartizites); Mem=Cluster Group Membership in *k*-means cluster analysis where number of clusters=3; RI- Resharpening Index

The mean values of these three clusters are significantly different along both variables according to the ANOVA test accompanying the k-means cluster analysis output (for standardized ground width, the ANOVA indicates the means are significantly different at the 0.000001 significance level [F-ratio=38.06, Cluster Mean Square df=2, Error Mean Square df=16], while the means for standardized ground length is significant at the 0.000003 significance level [F-ratio=30.98, Cluster Mean Square df=2, Error Mean Square df=16]).

In order to validate these results the data were split into two subgroupings, each containing roughly half of the artifacts from each cluster. The results indicate a strong overall partition of the data, as 18 of the 19 artifacts retained their group membership throughout the split validation. The secondary validation technique involves using three different clustering algorithms to test how well the clusters hold given different grouping algorithms. Separate hierarchical analyses were run using Within-group linkage, Ward's Method, and Centroid clustering algorithms, each employing Squared Euclidean distance as a measurement interval. Each test yielded results with 18 of the 19 observations retaining the original cluster membership determined through *K*-means analysis. All validation tests suggest the initial *K*-means partition is valid and reliable. Therefore, haft-area morphological attributes appear to cluster into three internally consistent groups, or potentially two groups with an outlier present.

Two potential explanations for the observation of the standardized pattern obtained above seem plausible. First, variability may indicate distinct mental templates for point size and form within an aggregated group. This pattern could have been produced through the presence of specialists or by the use of distinct mental templates employed by different members of the same group. Additionally, it could also represent two or three distinct bands within the aggregated group, each with an idiosyncratic template. Wilmsen (1974) has made such an argument as an explanation for variability among Folsom points at Lindenmeier for example. Second, the clusters may represent functionally distinct weapons (i.e. Cluster 1 may represent dart points, while Clusters 2 and 3 may represent thrusting spear points). At this point, the data is not sufficient to privilege one hypothesis over another. Such analysis is a promising avenue for future research.

In order to make an argument about the potential for sharing among hunters during the hunt, one must demonstrate that foreshafts or hafting elements are standardized to a degree where interchangeability is practical. As we do not have the remains of any foreshafts to observe, we need to demonstrate the possibility that a single haft size *could* secure each weapon in the assemblage *within a single internally homogenous cluster*. In order to explore this, the maximal ground width for each cluster will be compared to the smallest value within each cluster to determine if both points could feasibly function in the same sized haft. Width of the haft and ground width must be nearly equivalent, as too much space between haft and point would cause significant horizontal instability and limit functional utility as a result of extra resistance limiting penetrative efficiency.

In Cluster 1, the maximal ground width is 20.1 mm (Catalog #96228), whereas the minimum ground width is 15.0 mm (Catalog #OA051). If the smallest projectile point in the cluster was placed in a haft equal in width to the widest point within Cluster 1, there would be an excess width of 5.1 mm resulting an extra 2.5 mm between projectile point edge and haft wall on either side of the point. Practically speaking, this amount of space would likely cause minimal, if any, oppositional penetrative resistance inhibiting effectiveness of the functionality of the weapon. In order to confirm this hypothesis, and determine the amount of excess space that inhibits penetration to a detrimental extent, one would need to conduct some form of ballistic analysis. However, at a practical level, an extra 5.1 mm would not likely cause any functional issues with a weapon if all haft sizes within the cluster were identical, as the space could be filled with leather or hide to secure the point.

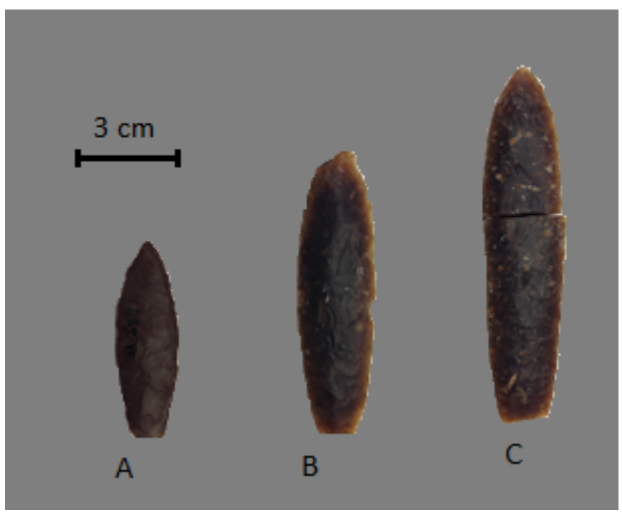

Figure 4. Image of Representatives of Each Cluster Observed. A) Cluster 1, Catalog Number OA287; B) Cluster 2, Catalog Number 96107a; C) Cluster 3, Catalog Number 96601/96237

In Cluster 2, the maximal ground width is 25.8 mm (Catalog #98605), while the minimal ground width is 21.5 mm (Catalog #96107a). The range within this cluster is 4.3 mm. As this value is less than the maximal range of variability in

Cluster 1, it suggests this amount of excess width would not alter the ability for the smallest weapon in Cluster 2 to function in the same haft as the largest point. Finally, the difference in ground width between the two artifacts in Cluster 3 is 2.8 mm. Thus, there should be no functional issue if both of these weapons were hafted in the same sized haft. As noted above, the only way to test if the excess spaces hypothesized in these examples are functionally significant is via ballistic tests using Agate Basin replica points. On a practical level, however, it appears that each standardized cluster may potentially represent a single standardized haft size. Therefore, weaponry at the Agate Basin site appears to have been highly standardized, allowing the potential for sharing between most if not all hunters prior to and during hunts.

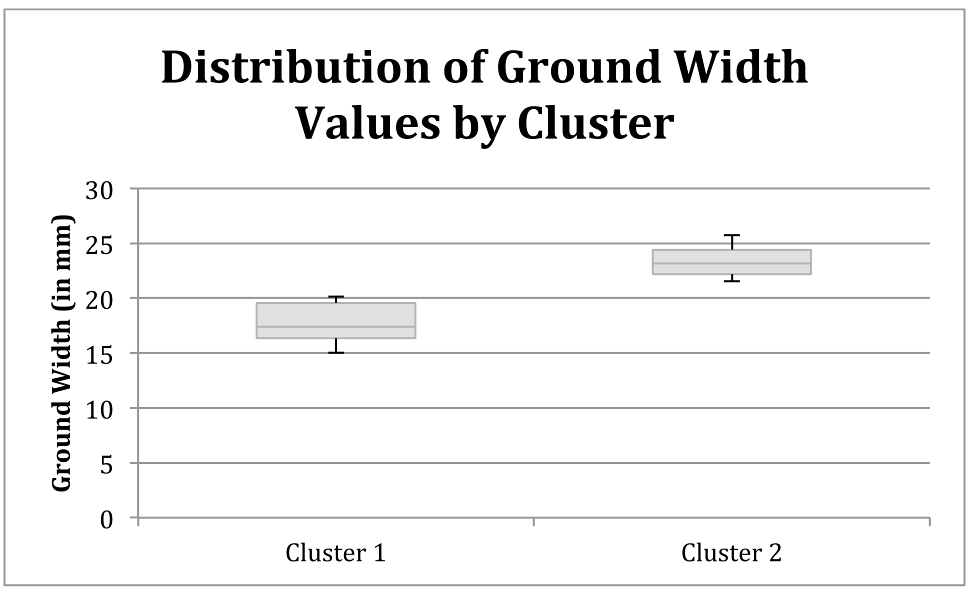

Figure 5. Box-plot of Cluster 1 and Cluster 2 Distributions of Ground Width

Discussion

As argued above, the Agate Basin projectile point assemblage appears to represent a highly standardized weaponry system. How was such a system organized and maintained in order to function effectively at an aggregated hunting event? One scenario involves gearing up immediately prior to a hunt, after the group had aggregated. If gearing up took place directly prior to a communal hunt at an aggregated-group level specifically for the hunt, we would expect to see a majority of the points recovered from a kill site to be full-size and minimally reworked (see Weltfish 1965 for an ethnographic description of gearing up prior to a large-scale bison hunt). Additionally, we would expect to see minimal raw material diversity, as one lithic source would likely dominate the assemblage (Sellet 2004). On the other hand, if groups prepared prior to aggregation, we would expect to see raw material diversity reflect the different territories occupied by distinct groups while dispersed. These hypotheses can be tested using a resharpening index, which measures the amount of resharpening which took place from the time the point was manufactured to the time it was discarded, and observation of raw material for the points in the assemblage.

The resharpening index indicates the amount of use and maintenance of a specific point since the last manufacturing or refurbishing event for the user of that point. The formula for calculating the resharpening index as defined here is as follows:

Resharpening Index = actual unground length/projected unground length

Unground length is the length value from the distal tip to the horizontal plane marking the location where marginal grinding terminates (see Figure 2 on page 18).

The formula for determining the projected unground length was generated by plotting ground length against unground length on points determined to be "non-resharpened" (n=7), then using the best-fit regression line (r^2=0.81) equation to solve for projected unground length.

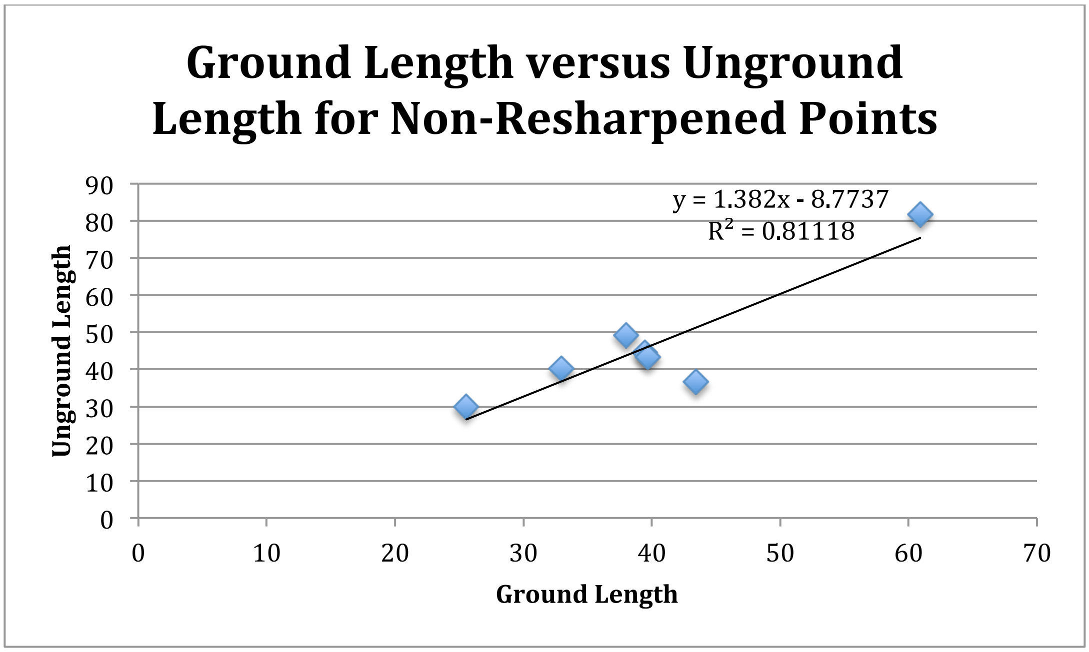

Figure 6. Ground Length Plotted Against Unground Length for Non-resharpened Points (n=7)

The equation for the best-fit regression line for these two variables is as follows:

y (projected unground length)= 1.382 * x (ground length) – 8.7737

According to the index developed, higher values (around or above 1) indicate minimal resharpening, with lower values indicating higher intensity of maintenance. If we apply this to the hypothesis suggesting communal gearing up prior to a big game hunt, we would expect to see a majority of the weapons in the assemblage to have values indicating minimal amounts of resharpening. The histogram below illustrates the distribution of the Resharpening Index data.

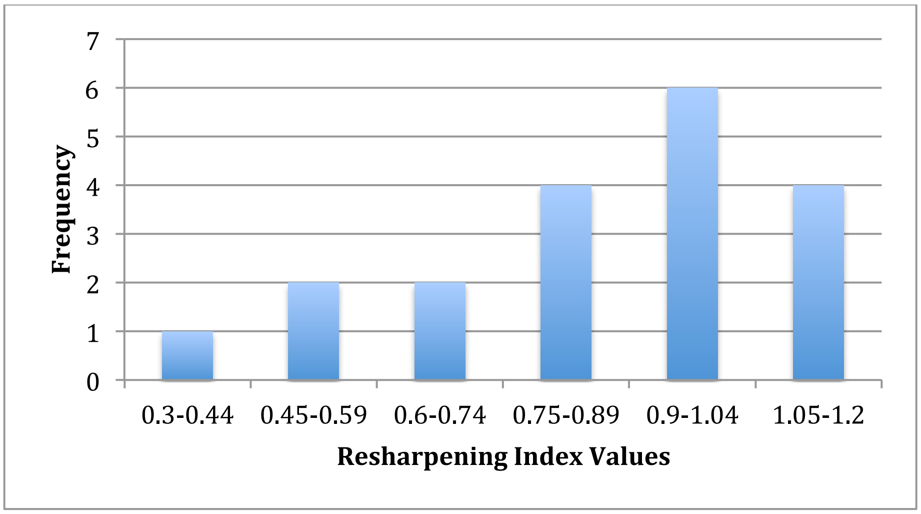

Figure 7. Histogram of the Distribution of Resharpening Index Values (n=19)

The data indicates that 10 out of the 19 complete points examined had RI values of 0.9 or larger, while the other nine points fell below this arbitrary threshold. While these data suggest many of the points were not used intensively prior to the hunt, the distribution of RI suggests weapon manufacture and maintenance was not exclusively done via gearing up *after* the group had aggregated specifically for the hunt. Raw material variability within the clusters likewise suggests multiple sources of tool stone within each standardized weapon delivery system, inconsistent with the hypothesis that organization of the weaponry system occurred exclusively via gearing up after the group aggregated (see Table 1 on page 8 for raw material sources and distances from Agate Basin site). The variability in raw material source locations likely represents groups who occupied distinct territories and exploited distinct sources of tool stone in preparation for the hunt (Ingbar 1994). A scenario where individual bands geared up in anticipation of a communal hunt *prior to* aggregation into the larger group explains the large range in RI values, as weapons of bands that retooled at different times and used their weapons to varying degrees would result in a pattern where amounts of resharpening at a very specific time were variable. This is not to say, however, that gearing up in preparation specifically for a communal hunt did not occur. On the contrary, the left-skewed nature of the distribution indicates that we see a majority of the projectile points examined with RI values above 0.75, which still indicates a relatively minimal amount of use and resharpening after manufacture.

Table 4. Raw Material Distribution for All Complete Points Used in Study

Raw Material	**Count of Complete Points**
Knife River Flint	10
Other Chert	6
Quartzite	3

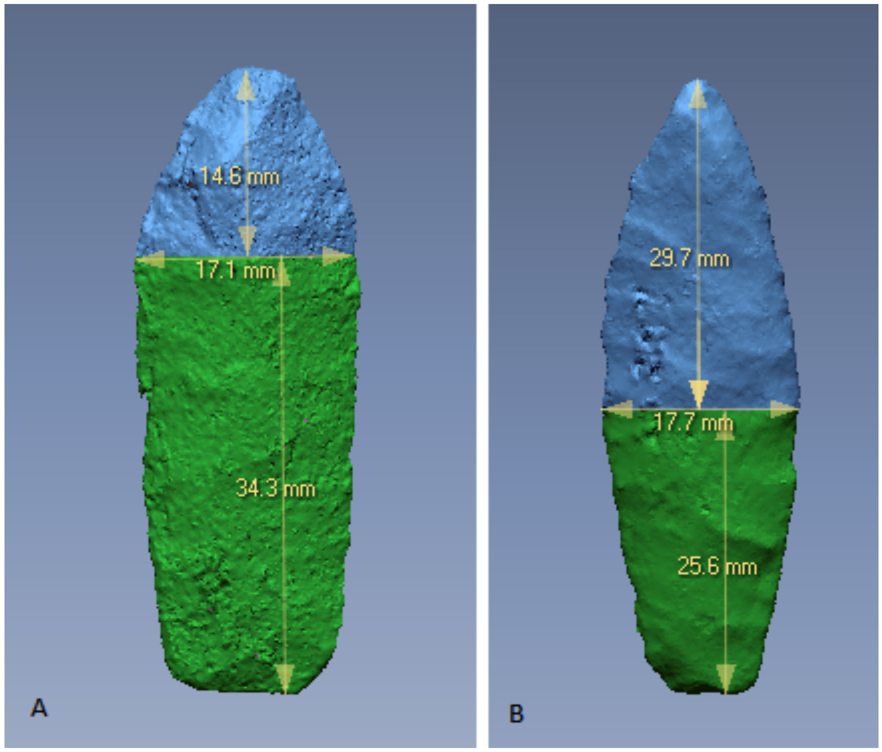

Figure 8. 3D Scans Demonstrating Different Resharpening Index Values; A) Catalog Number 96076, RI value= 0.38; B) Catalog Number OA287, RI value= 1.13. Green marks hafted area, blue marks unhafted area.

The hypothesis posed here argues that gearing up likely took place at the level of individual bands prior to aggregation at the Agate Basin site. These individual instances of gearing up may not have occurred at the exact same time, and new weapons may have been used with differential intensity prior to aggregation, resulting in slightly different patterns of maintenance and resharpening suggested by the Resharpening Index. This leaves the points with demonstrably lower RI values unexplained. However, one could argue that to better ensure success, hunters would take any weapons retaining any utility as insurance against an insufficient number of weapons during the hunt. This strategy fits well with the general organization of technology emphasizing weapon exchangeability and replacement during the hunt.

The question now becomes: how did groups, who geared up independently, consistently manufacture weapons with standardized haft-area morphologies? The specific organizational mechanism in play, at this time, is unknown. The critical idea to be taken from this discussion, however, is that these weapons were highly standardized at the group-level, while gearing up appears to have occurred at the level of individual bands prior to aggregation. The end result was likely a cooperative hunt with the potential for sharing between members of different bands.

The most effective method for contextualizing the data from the Agate Basin site in terms of sharing is to discuss how sharing of weaponry elements relates to strategies of reliability or maintainability emphasized in a technological system (Bleed 1986; Hayden et al. 1996). These concepts imply certain technological emphases that inform arguments not only about specific attributes of a weaponry system, but also potential influences for why such systems are needed and under what circumstances they are used. Reliable systems are systems in which the design, manufacture, and maintenance of the artifacts ensures function when weapons are in use (Bleed 1986:739). Strengthening, size increase, and overdesign of crucial components are key attributes of reliable systems, as are manufacturing redundant (e.g. a quiver of identical arrows) and standby parts. (Bleed 1986:740). In terms of organization, manufacture and preparation of tools is often done in advance of needs, and likely represent exclusively curated weapons (Binford 1979; Bleed 1986:740). Reliable systems are ideal when the consequences of system failure are significant, when schedules follow a predictable pattern of use and downtime, or when hunters either focus on specific large game or seasonally take abundant game (Bleed 1986:741). Maintainable systems, on the other hand, are those in which broken or ineffective tools can quickly be brought into a functional state (Bleed 1986:739). Common attributes of maintainable systems include simpler design of tools, the presence of specialized repair kits, and a tendency for each part to serve its own unique purpose in the design in such a way that if one component fails, the entire tool fails (Bleed 1986:740). In a scenario in which a component fails, maintainable systems often employ easily replaceable components to ensure the tool or weapon is functional (Bleed 1986). From an organizational standpoint these kinds of systems are ideal for unpredictable schedules (Bleed 1986:741). Expedient tools are indicative of maintainable systems, although maintainable systems are not exclusively or even predominantly expedient (Bamforth 1986; Binford 1979). Weapons designed for encounter hunting irregularly available game fall within this category (Bleed 1986:745). One must keep in mind, however, that reliable and maintainable systems are not mutually exclusive, as technological systems can emphasize elements of both in response to specific adaptive needs.

At the Agate Basin site it is clear, based on technological attributes and hypothesized organizational factors, the weaponry system emphasized reliability. Technologically, the Agate Basin system utilized careful crafting of spear and projectile points based on the standardized nature of the haft area of recovered weapons. Standardization of weapons under rigid constraints, and large numbers of weapons manufactured well in advance of time of use (Eerkens 1998) ensured that the weaponry system was ready for use when needed and had enough parallel or replacement parts which could have been used in case of failure of an individual element, a trademark of reliable systems (Nelson 1991). Nelson (1991:69) argues that reliable designs "may be seen in assemblages by the occurrence of standardization of haft form and size", something explicitly argued for here. Standardization of weaponry elements at Agate Basin reflects a method of weaponry manufacture allowing quick exchange and replacement *among* hunting kits during the hunt, hallmarks of reliable weaponry systems.

Organizationally, the Agate Basin site exhibits other characteristics of a reliable system specifically in terms of planning or gearing up for a hunt, aggregation hunting strategies, and risk reduction. Gearing up reflects a reliable system due to the predictive nature of provisioning a weaponry system prior to a planned hunting event. Preparation for the Agate Basin hunt encompassed predicting future needs prior to the event, and ensured that the system was ready well in advance of the hunt. Gearing up, along with producing standardized weapons, manufacturing extra weaponry elements to prevent individual element failure, and overdesign of elements, is a form of risk reduction employed by hunters using a reliable weaponry system. Each of these characteristics is reflected in the Agate Basin assemblage. Sharing of weaponry fits in well with this pattern of risk reduction in that the ability to share elements of a weaponry system enabled hunters to stay active in a given hunt longer than if weapons were individualized and not meant to have been exchanged or borrowed. Exchange between hunters had to have been anticipated during the manufacture, maintenance, and organization of technology, and built into the design of weapons in the form of standardized weaponry elements. The Agate Basin assemblage, as a tightly standardized assemblage, thus had the *potential* for sharing built into it at the aggregated-group level, a decidedly reliable characteristic.

Each of these attributes of reliable systems at Agate Basin was designed to reduce risk of failure in the context of an aggregated-group communal hunt. Even the concept of communal hunts itself embodies reliability, as risk reduction is a primary incentive for aggregating and participating in communal hunting (Hofman 1994; Bamforth and Bleed 1997). Thus, it would appear that reliable technological systems are an essential component of communal hunting due to the amount of planning and organization required. Sharing of weaponry elements becomes just one possible organizational mechanism developed to increase success at a communal hunt. In this sense, the assemblage from Agate Basin can be seen as just one line of evidence in approaching the greater question of technological organization during Paleoindian communal hunts at a much broader scale. Indeed, Bamforth and Bleed (1997) argue that Folsom groups likely reduced risk of starvation through organization of communal bison hunts during seasons of resource stress. Thus, the ideas of standardization, aggregation, communal hunting, reliable technological systems, and potentially sharing practices can all be seen as methods through which Paleoindian hunter-gatherers, as a broad category of human beings, organized themselves in order to ensure the bulk acquisition of vital resources during times when resources might not be as readily available as others.

Conclusions

The ultimate aim of this study was to explore the potential for sharing of weaponry elements, and the implications of such behavior as they pertain to organization of technology in the context of Paleoindian communal hunts. Data collected from a sample of 19 complete projectile points from the Agate Basin bone-bed at the Agate Basin site indicates a system that employed highly standardized weapons in the context of a communal bison hunt. Such standardization of weaponry elements enabled sharing prior to or during a hunt. It is critical to mention though that we cannot prove definitively that sharing occurred. The best we can do is construct a series of hypotheses regarding standardization of specific weaponry elements, which increases the ability for quick interchangeability of weapons while on a hunt. This study suggests a high level of standardization within the weaponry system represented at Agate Basin.

These results indicate a cooperative event at Agate Basin, where exchange was potentially facilitated among hunters, allowing for much greater efficiency during the hunt when compared to a system in which hunters primarily operate individually. The implications of aggregated group-wide sharing are significant. The hypothesized reliable technological system at Agate Basin encouraged standardization of technology at the aggregated-group level, thus enabling sharing of weaponry elements among hunters *from distinct bands* who aggregated only for a limited time throughout the year. This implies a mechanism to organize technology at the level of an aggregated group.

Determining the specific organization mechanism allowing for aggregated group-wide sharing is a promising avenue for future research. It is notable, however, that sharing of weaponry elements between members of different social bands during a communal Paleoindian hunt was possible, and this in itself allows us to conceptualize more firmly the level of cooperation involved in a communal hunt. In the Agate Basin case, sharing of weaponry elements, and the potential for such sharing, during a hunt minimized the risk of failure by ensuring that each hunter could remain active in the hunt for longer periods of time. Exchange between hunters guaranteed a maximum number of hunters remained active for as long as possible. This cooperation would have enhanced efficiency during the hunt and increased the number of animals killed. Sharing in this sense represented a method of risk reduction, which maximized success of the hunt during a time when failure to procure resources would have been catastrophic. Sharing became a method for reducing risk in conjunction and interacting with standardization, aggregation, and communal hunting as adaptive responses to environmental resource stress.

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